A dual *isotope approach* to assess controlled drainage as a *new mitigation measure*

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Introduction

Danish agricultural fields are extensively drained by subsurface pipes which are often transporting high amounts of nitrogen (N) directly to nearby streams with risk of eutrophication of freshwater and coastal water bodies. Since the loss of N from agricultural fields is the dominating N source to most surface waters, targeted mitigation measures that can assist in reducing N emissions are highly needed. The aim of this study was to investigate if:

i) Controlled drainage (CD) can assist in reducing N losses to surface waters.

ii) The stable isotope technique, $\delta^{15}N$ and $\delta^{18}O$ of NO_3^-, can be used to identify denitrification when using CD.

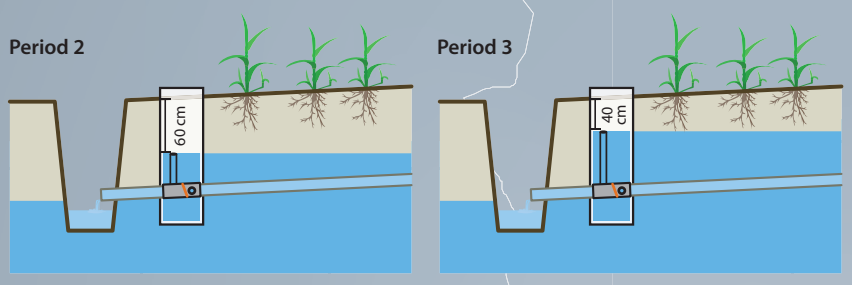

Figure 1. The groundwater table is controlled by adjustable regulation wells installed in the drainage pipe. The drain outflow level was 60 cm below ground surface (bgs) in period 2 and 40 cm bgs in period 3. in period 1 all subfields had free drainage.

Methods

- The effects of CD were examined during a three year period (2012-15) at three sites in Denmark (Fig. 2).
- A before-after control-impact (BACI) study design was used to determine the impact of CD on groundwater levels, drain flow, and N concentrations.
- The isotopic composition of $\delta^{15}N$ and $\delta^{18}O$ in NO_3^- of drain water was analysed in samples from a high and from a low flow event each month.

Figure 2. Location of the three study sites in Denmark. Two sites on loamy soil with respectively four and two subfields (Hedemarksvej and Bredkærvej) and one site on a loamy sandy soil with four subfields (Hofmansgave).

Acknowledgements

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Results

Groundwater levels were significantly increased at subfields with CD compared to subfields with free drainage (FD) at Hedemarksvej and Hofmansgave (Fig. 3). The plot at Bredkærvej appeared to be unsuitable for CD in the way it was introduced in this study. Drain flow rates were significantly reduced at both sites. The NO_3^- concentrations were significantly lower at subfields with CD compared to plots with FD at Hedemarksvej (Fig. 3), while there was no reduction of NO_3^- concentrations at Hofmansgave.

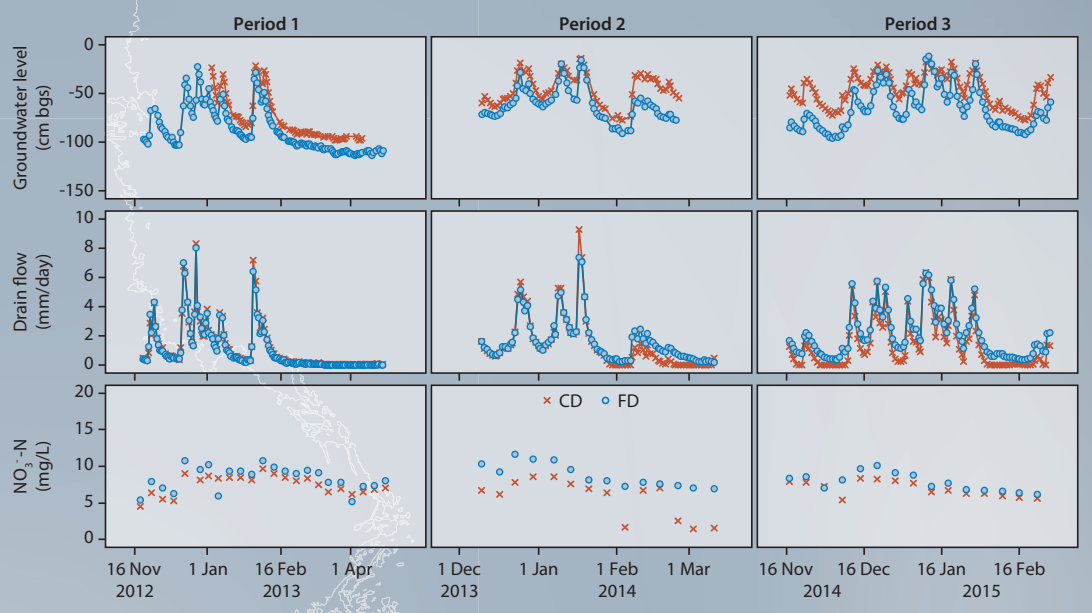

Figure 3. Groundwater levels (cm bgs), drain flow (mm/day), and NO_3^- concentrations (mg/L) for a subfield with CD and a subfield with FD at Hedemarksvej during period 1-3. In period 2 regulation level was increased from 60 cm to 40 cm bgs the 28 January.

Overall, drain outflow and NO_3^- loss were substantially reduced at Hedemarksvej and Hofmansgave by introducing CD (Table 1).

At Hedemarksvej there was indication of denitrification being a significant fractionation process at plots with CD when the drain outflow level was 40 cm bgs ($\delta^{18}O$/$\delta^{15}N$ 0.54-1) (Fig. 4). At Hofmansgave there was no evidence of denitrification being the dominating fractionation process ($\delta^{18}O$/$\delta^{15}N$ -1.9 to 1.3).

Table 1. The percentage effect of controlled drainage on drain outflow and N loss for drain outflow levels of 60 and 40 cm bgs at Hedemarksvej and Hofmangsave.

	Drain outflow level	Drain flow	NO_3^- loss
Hedemarksvej	60 cm bgs	-12%	-15%
	40 cm bgs	-44%	-47%
Hofmansgave	60 cm bgs	-65%	-60%
	40 cm bgs	-58%	-57%

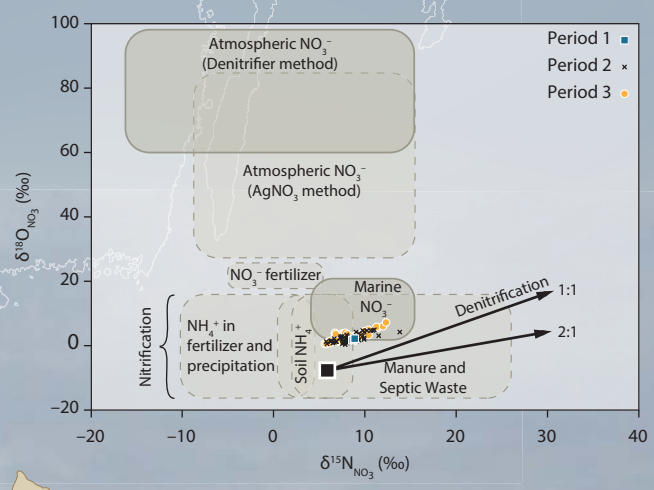

Figure 4. Measured dual isotope composition of NO_3^- from all sites in period 2 and 3 plotted with typical ranges of isotopic composition for NO_3^- sources modified after Kendall *et al.* (2007).

Conclusion

- The groundwater levels were increased at subfields with CD relative to FD at both sites.
- CD reduced the loading of NO_3^- from the drain pipes primarily due to the reduction of drain outflow.
- Denitrification in the root zone was not particularly enhanced by CD.

References

Kendall, C., Elliott, E.M. & Wankel, S.D. 2007. Tracing anthropogenic inputs of nitrogen to ecosystems. Stable Isotopes in Ecology and Environmental Science. 2nd edition ed.: Blackwell Publishing.